# THE ETIOLOGY, PATHOLOGY AND OPERATIVE TREATMENT OF RACHITIC DEFORMITY, AS BASED UPON ONE HUNDRED AND FIFTY-EIGHT CONSECUTIVE OSTEOTOMIES, WITHOUT SUPPURATION.[1]

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ANY ONE who has read Sir Walter Scott's touching and sympathetic story of the "Black Dwarf" can appreciate the intense mental suffering which a person of a sensitive and highly organized mental constitution experiences on account of marked bodily deformity. This ideal being, who was represented as residing in solitude, haunted by a consciousness of his own deformity, and a suspicion of his being generally subjected to the scorn of his fellow-men, was not altogether imaginary. As he says of himself, "I am a poor miserable outcast, fitter to have been smothered in the cradle than to have been brought up to scare the world in which I crawl." The sense of his deformity haunted him like a phantom, until at last, he became alternately a pilgrim and a hermit, suffering the most severe privations, not indeed in ascetic devotions, but in abhorrence of mankind. Such a character could only have been suggested by a close and intimate acquaintance with rachitic deformity.

Rachitis is a disease of early life. All who are connected with our large dispensaries must have observed the great prevalence of this disease among the applicants for medical aid

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[1] Read before the American Orthopædic Association at the Congress of American Physicians and Surgeons, Washington, September 17, 1888, with presentation of 100 original photographs.

While more common among the children of the poorer classes, still it is not infrequently met with among the children of the better classes of society, perhaps not in its most advanced stages, yet it is sufficiently well marked in some of its manifestations to be easily recognized. While not so common in this country as in some of the European countries, yet according to Dr. Parry, in the Philadelphia Hospital, 25% of all the children between two months and four years of age are rickety, while in some of the European countries, especially England, Scotland and parts of Germany, the proportion is even greater. The recent report of the collective investigation committee of the British Medical Association states that rickets, though not unknown in rural districts, is mainly a disease of towns and industrial regions and especially of large manufacturing towns. In the densely populated and industrial portions of England and Scotland it is especially prevalent, and is all but universal in Glasgow and its suburbs. In the New York Infant Asylum, a few years since, one in every nine, by actual count, presented marked rachitic symptoms. In this country the disease occurs for the most part in children whose parents were born in Europe, principally the Anglo-Saxon and Latin races. It is comparatively rare in children of native Americans, with the possible exception of the Negro race, among whom it prevails to a most astonishing extent.

Rachitis or rickets is a disease that should command not only the attention of the surgeon, but that, of the general practitioner as well, in order that its results, deformities of the limbs and abnormal shapes of the chest and pelvis, may be prevented. Rachitis has been defined by Bouvier as an affection of the young, a vice of ossification, with softening, curvature and deformities of the bones. This definition is clear and precise, and is founded on a lesion and a condition which is anatomically well characterized, but it does not fully cover the ground. Rachitis is a general constitutional defect, and the osseous structure is involved in common with every other tissue of the body. It should be remembered that rachitis is not a disease of the bones alone, but according to the most recent writers is a general nutritive disorder which affects all structures, not only bone but muscles, ligaments, skin, mucous membrane, the blood, arteries and the nervous system. It is complicated with or dependent on disorders of the digestive or respiratory apparatuses, which are preceded by a disposition probably created by an undue width of the arteries. (Jacobi).

One of its prominent symptoms is muscular debility—sometimes so great as to be mistaken for actual paralysis. The patient may appear plump and fat, but his muscles are flabby.

Changes in the subcutaneous tissue are also present; fat is either present in excessive amount, or deficient. Changes in the mental and moral faculties, are also present. Enlargement of the spleen, liver and of the lymphatic glands. in different portions of the body are common accompaniments of this disease. Rachitis affects the growth of the teeth. The appearance of the teeth is retarded, or if they make their appearance they soon drop out. Sir William Jenner states that if the child have no teeth by the ninth month, it is probably rachitic. Usually only one set appears and these are wide apart and few, as seen in Fig. 18. This fact will be further illustrated in the cases to be presented.

While the above mentioned symptoms are manifesting themselves, most important changes are taking place in the bones. These consist in an hyperæmic condition of the primordial cartilages of the epiphyses, with copious deposits of new material in that region and also under the periosteum with softening of the diaphyses, so that curvatures occur, and while this process continues, true ossification of the bones does not progress.

HISTORICAL.—There is good reason to believe that this disease was described by Hippocrates and Galen. Bœtius and Serverin, who claim that there can be no complete medical histories without the mention of these names, have found among the writings of these authors descriptions of diseases analagous to rachitis. Others believe that there has always existed a species of rachitis, even although this affection was never scientifically described.

Literature has preserved even to our times types of deformity such as that of Æsop and Thersites, who lived centuries ago and presented apparently types of rachitic deformity.

The first scientific description of the symptoms and pathology of this affection was written by Whistler and appeared in England in the early part of the 17th century. While to England belongs the honor of first describing the disease, it has also the not so enviable distinction of having the disease denoted by its adjective appellation, for rachitis still goes by the name of the English disease; in French, Morbus Anglicus; German, Englische Krankheit. Glisson, about the year 1650, gave a description of the disease and used the term rachitis.

Etiology.—In studying the etiology of rachitis we must approach it from two points of view, its predisposing and its direct causes. The predisposing causes of rachitis have been studied by Beneke from an anatomical standpoint. He found that the arteries in rachitical patients were abnormally large.

In three cases where the arteries of the neck were unusually large, the children died young, one of hydrocephalus, one of an abnormally large skull and one suddenly. The period of life at which the arteries are found to be abnormal corresponds to the time at which the rachitic process is most marked, viz.; the second to the fourth years of age. This affords an explanation of the hyperæmic condition of the bones, especially at the junction of the epiphysis, where the growth of the bone is most active, and also of the increase of development and eburnation of the bones after the morbid process ceases.

As above stated in rachitis the normal proportion of the blood vessels to the heart is greatly changed. Of this Jacobi, well says (Address, Febuary, 1887): "As it is not probable that a chronic disorder in its slow progress should work a rapid change in the blood vessels, the inference is a sound one, that if the disorder can not have altered the blood vessels, these must have given rise to or be connected with the nature of the disorder.

"For instance, in rachitis the heart is of average size but the arteries are abnormally large. Great width of arteries lowers blood pressure."

Thus is best explained the murmur first discovered by Fisher, of Boston, over the fontanelles of rachitical babies, very much better than as Jurasz asserts by osseous anomalies in the carotid canal. Another result of the low blood pressure is the retardation of the circulation in the muscles, with flabbiness and incompetency as consequences, and still more about the epiphyses, which swell and soften. It is very much less the cartilaginous condition of the epiphysis which gives rise to rachitis (for some of them do not ossify before the twentieth year or later, at a time when no rachitis is observed) than some constitutional disorder of which the principal one may be, as stated, the unusual size of the blood vessels. There are other anomalies in rachitis which aid in the retardation of circulation, viz. : the large size of the liver and the smallness of the lungs. Through these influences ossification becomes irregular and defective. The slowness and irregularity of the circulation, dependent on these conditions, together with the watery condition of the blood, are the predisposing causes giving rise to catarrh of the pharynx, larynx and respiratory organs in general, with which rachitical subjects are so generally affected.

There is another interesting consideration to which one writer has drawn attention: Owing to the relatively large diameter of the arteries a greater number of red blood corpuscles is required in order to properly fill them. Now, in the rachitic, owing to the impairment of the digestive and hæmatopoietic organs, the blood-making processs is not so active, so the tissues must necessarily show the effect of the relative increase of the watery constituents of the blood, a condition which the biochemists have found to uniformly exist in the rachitic.

In the healthy infant the pulmonary artery is larger than the aorta by not more than four millimetres. In the rachitic subjects examined by Beneke, the pulmonary artery was found to be proportionately much greater in size, thus affording an anatomical explanation of the pathological processes so frequently found in the lungs of the rachitic. For, while the amount of blood carried to the lungs is relatively greater than in the normal condition, owing to the disease of the bones of the chest, the lung space is contracted and consequently the circulation of blood in the lungs is impeded.

There is also a variation of size in the other organs of the rachitic, and the combination of variability found in the rachitic subject does not correspond with that found in other constitutional disorders, as for instance in scrofula, Beneke found a small heart, unusually narrow arteries and a small liver. From these considerations the conclusion is drawn that these variations of size are not the results of the disease, but that they are congenital and stand in some causal relation to it.

The direct cause of rachitis was attributed by Glisson to the inequality of nutrition by the arterial blood, and curvature of the long bones to their superabundant vascularization.

John Mayow (1761) held a disturbance of the innervation responsible; Zeviani (in the same year) improper food in general and particularly prolonged lactation; others have attributed it to an undue production of acid and the softening of the osseous tissue thereby. C. Heitzmann fed both herbivarous and carnivorous animals with lactic acid and found the cortical layers of the bones softened and the medullary substance hyperæmic and claimed to produce osteo-malacia in the former and rachitis in the latter. It cannot be doubted that rachitis occasionally occurs as a congenital disease.

Cases have been reported by Chiari, Jacobi, Burrall and Gueniot. Kassowitz examined many still born infants and also children dying shortly after birth, and in a large majority found rachitical changes in the ends of the bones. In many of those, who lived several weeks after birth, the rachitical changes were advanced to such a degree that its uterine origin became clearly demonstrated. I have observed well marked bowing of the tibiæ at birth. That direct inheritance is not a constant or essential factor is proved by the fact that perfectly healthy parents, who have never been rickety and show no trace of it may have and constantly do have rickety children. We may then eliminate inherited tendency, at all events, as an essential condition.[1]

Schwartz (*Med. Woch.* 1887) has demonstrated by an examination of 500 children within an hour after birth at the lying-in hospital in Vienna, that the signs of rachitis can usually be found at that early period, showing the disease to be, at least occasionally, intra-uterine in its commencement. Of the 500 children, 97 were without signs of this disease; 188 had well marked rachitic rosaries together with rachitic changes of the cranial bones, varying from an abnormal weakness along the border of the sagittal suture to an almost complete defect of ossification of the cranium; 155 had well marked rachitic rosaries without the changes in the cranial bones; 36 had the changes in the cranial bones alone, and 24 presented only slight swellings at the unions of the bones and cartilages of the ribs. Of the children born in the seventh lunar month, 14 were rachitic, 1 normal; in the eighth lunar month 27 rachitic, 4 normal; in the ninth lunar month, 50 rachitic, 12 normal. Fifteen of the mothers of rachitic children presented signs of having suffered from a high grade of rachitis. Of six cases of twins, in 3, one child was normal, while the other was rachitic, in the other three, both children were rachitic.

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[1] Dr. W. B. Cheadle. Brit. Med. Jour.

His conclusion is that every child should be examined as soon after birth as practicable, and if any signs of rachitis are found to be present, active treatment should be immediately instituted. (*N. Y. Med. Jour.*)

Rachitis is a disease occurring during the rapid development of the tissues, therefore anything that interferes with normal growth and development is apt to change physiological function into a pathological condition and produce rachitis. Therefore all influences that impair the nutrition and injure the strength in parent or the child itself, such as bad feeding, foul air, damp, cold rooms, want of sunlight, want of exercise and want of cleanliness must be looked upon as predisposing causes of this disease.

Of the many special causes that have been brought forward at one time or another as the essential agent in the production of rachitis, that of special defects in diet or a faulty composition of the child's food has perhaps the strongest claim on our attention. In a discussion on rickets at the annual meeting of the British Medical Association, August, 1888, Dr. W. B. Cheadle in introducing the subject, claimed that "the food factor is the only factor which is anything like constant." He believed it traceable in every instance. Syphilis may be absent, hereditary taint may be absent, all external condition of mal-hygiene may be absent ; yet, in spite of this, a child brought up on artificial food may become rickety. The fault lies in some defect in the artificial food, in some quality in which it differs from the non-rachitic food of human milk. The form of improper feeding most frequently associated with a rickety constitution is a farinaceous diet.

An examination of the different artificial foods shows a grave defect which is common to all; they are remarkably deficient in two important elements.

The abundance of fat in human milk, constituting as it does one-fourth of the whole solids, indicates its extreme importance as a constituent in the food of the growing child.

An inquiry into the diet of the rachitic children that have come under my observation supports the views of Dr. Cheadle. Many of them have been fed on diluted condensed milk or other foods in which animal fat and easily digested proteids are conspicuously absent. Several of the children while under treatment have shown an aversion to butter and milk, and inquiry has elicited the fact that those articles of food have formed a very small proportion of their former diet. In support of his views Dr. Cheadle cites the experiments in the feeding of the young animals in the Zoological Gardens, London. A single example will illustrate : It seems that the young animals are extremely liable to become rachitic there. In rearing the young lions, as a rule, the lioness can not be trusted to suckle her cubs ; she either injures them or neglects them and they have to be fed by hand. The food on which they have hitherto been fed, the flesh of old horses, is almost destitute of fat.

The bones were found to be proof against the teeth of the adult lions even, and those of the cubs were powerless to deal with them. Once a week they were given goat's flesh, which is also poorly supplied with fat. This diet would be especially deficient in fats and the earthy phosphates. The feeding of the last litter of lion cubs was commenced in this way : "They quickly developed marked rickets and one died. Then, at the suggestion of Mr. Bland Sutton, the diet was changed. The meat was continued, but in addition to it cod liver oil and pounded bones were given with milk. No other alteration whatever was made in any way. In three months all signs of rickets had disappeared; and now at eighteen months old, they are perfectly strong and healthy and well developed, a unique event in the history of the Society."

He sums up the general pathology of ordinary rickets thus:

1. It is primarily a diet disease which can be caused at will by a rachitic diet just as certainly as scurvy by a scorbutic diet, and which can be cured as certainly by an anti-rachitic diet as scurvy by anti-scorbutic diet.

2. That the chief defect in diet which causes rickets is want of animal fat.

3. With this probably also deficiency of the earthy salts in form of phosphates.

4. A deficiency of animal proteids in conjunction with the preceding intensifies the condition.

5. The rickety state is accentuated by evil hygienic conditions, such as foul air and want of light, although these are not essential to its production.

6, Rickets is modified in character by the concurrent existence of congenital syphilis and of scurvy.

CHEMISTRY.—Defective calcification of the forming bone is one of the leading features of rachitis. The normal proportion of lime does not enter and cannot remain in the osseous tissue, but is rapidly eliminated by the kidneys and intestinal tract. One hundred parts of bone, according to the analysis of Gorup Besanez, contain:

| | OSSEIN. | PHOSPHORIC ACID. | LIME. |
|---|---|---|---|
| Healthy bone - - - - - - | 34 | 26 | 34 |
| Rachitic femur - - - - - - | 72 | 7 | 9 |
| Rachitic tibia - - - - - - | 60 | 12.9 | 17 |

Thus chemical analysis confirms the experiments of the pathologist.

PATHOLOGICAL HISTOLOGY.—Rachitis is for the most part a disease of the osseous tissue occurring during the period of development of the bones. It is characterized histologically by disturbances of nutrition of the tissues that contribute to the development of the bones. We must then look for the pathological changes attending this disturbance of a physiological process at the points where the growth of bone occurs, viz., the peritoneum and the places of apposition between epiphysis and diaphysis.

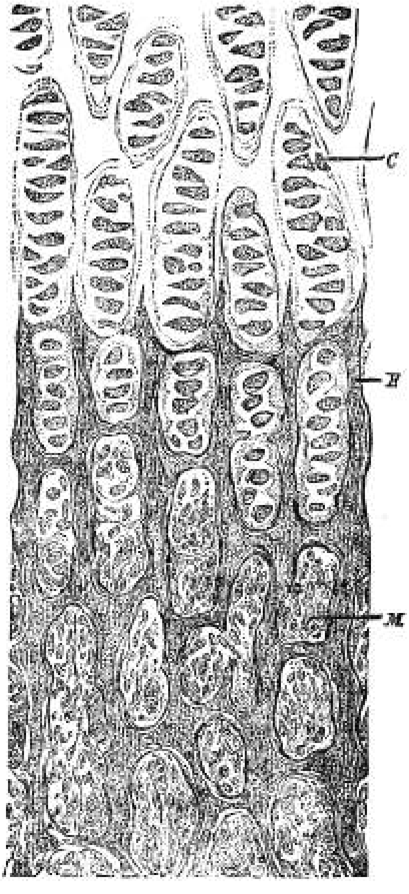

FIG. 1.—HUMERUS OF HUMAN EMBRYO, FIVE MONTHS OLD. SAGITTAL SECTION.—*Heitzmann.*

C, Rows of cartilage corpuscles in elongated groups, due to their territories. F, Frame of calcified basis substance, around which, in the lower portion, the first traces of bone-tissue are noticeable. M, Medullary space, containing medullary corpuscles. (Magnified 500 diameters).

*Normal Ossification.* The long bones are developed from cartilage. The skeleton of the embryo is first formed in cartilage and normal ossification occurs with great regularity. This precursory cartilage may be regarded as a temporary substitute for bone, affording, as it were, a mould of definite figure and form in which the osseous material may be deposited. A section of the bone shaft of a human embryo, at about the fifth month, shows that it is composed of hyaline cartilage, with many medullary spaces. At the point where calcification first commenced the cartilage cells became arranged in regular rows. At this point the basis substance is soon found to be the seat of calcareous deposition. This is beautifully shown in the accompanying drawing (Fig. 1). If we examine minutely a section of an ossifying bone, it may be observed that the cartilage cells at a distance from the ossified part are uniformly disseminated in the matrix, but when at or near the points of ossification, the cells are arranged in rows or oblong groups, between which the transparent matrix appears in the form of clear longitudinal lines, obliquely intersecting each other at intervals. At a point lower down it may be observed that this matrix, together with portions of the capsules of the cartilage cells, have become the seat of an earthy deposit.

So that the new calcareous material at first forms oblong areolæ, or loculi, enclosing the groups of cartilage cells. But this process of calcification which differs from that of the true bone formation is only transitory, and a short distance below we see a change taking place in the newly formed tissue. The primary areolæ, above described, open into one another both laterally and longitudinally, and by their coalescence give rise to large secondary or medullary spaces. The primary calcareous plates are all finally absorbed, while the walls of the medullary spaces are thickened by the deposit of layers of new bone. The calcareous deposition occurs only in the broad masses of basis substance, between the region of the cartilage corpuscles, and lower down the spaces are filled with medullary corpuscles. At the lower portion the first traces of new bone can be seen in the form of bright rings attached by their convex surfaces to the calcified frames. This frame work of calcified tissue is soon dissolved and the cartilage cells proliferate, forming medullary cells. True ossification now begins. Some of these cells begin the formation of bone tissue, while others are surrounded by the osseous substance and become bone corpuscles.

*Ossification in Rickets.* We have seen that in the normal process of ossification the cartilage is reduced to an embryonic condition giving rise to medullary cells. At the same time the formation of new blood vessels occurs. In rickets all this preparatory process is going on at a more rapid rate, but the formation of new bone from the medullary tissue is very scanty or entirely absent.

In a sagittal section of the epiphyseal end of a rachitic bone we notice a zone of an intensely reddish color at the point of transformation of cartilage into medullary tissue. The cartilage cells contain a larger amount of bioplasm than normal, the calcification of the cartilage is scanty or absent and occurs in irregular patches. An increased formation of blood vessels occurs. At the peripheral portion of the epiphyseal cartilage a formation of vascularized cartilage, instead of bone can be traced, while the newly formed trabeculæ of bone are scanty, irregular in shape and filled with large bone corpuscles. This is well shown in Fig. 2.

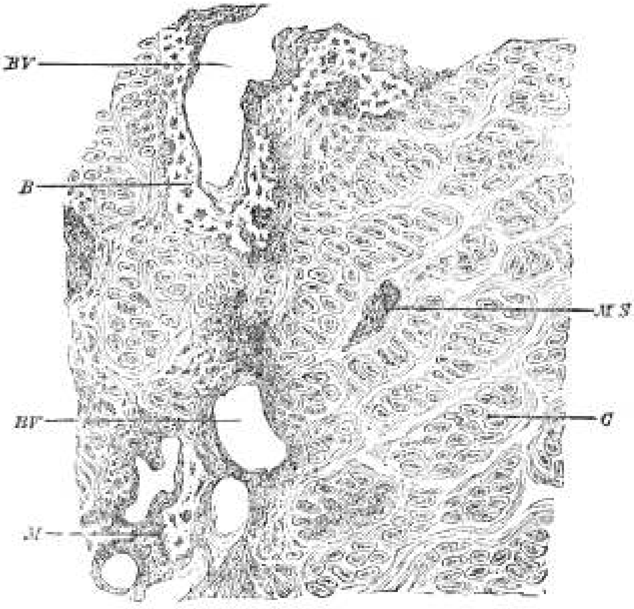

FIG. 2.—RIB OF A RACHITIC CHILD IN TRANSVERSE SECTION.—*Heitzmann.*

C, Cartilage corpuscles arranged in territories. MS, Medullary space sprung from cartilage tissue. M, Medullary tissue with very large blood-vessels, BV. B, a scanty new formation of bone tissue. (Magnified 200 diameters).

At the borders of the bone shaft we find between the thin cortical bone tissue and the fibrous portion of the periosteum a broad layer of medullary tissue. The vascularization of this tissue is so great as to give rise to the appearance of a hemorrhage.

The bone generally remains in a stage of cancellous structure with large irregular spaces.

As Kassowitz well says, lime cannot be deposited in the immediate neighborhood of a copious blood supply. But why does the rachitic process have a special affinity for the growing bone?

Kassowitz urges that the growth of bone differs from all other tissues, in that the latter grow uniformly throughout their whole mass, that the circulation in them is more uniform and carries nutrition into and through every particle simultaneously, while in the bones the only places in which the whole circulation can contribute to their growth are the epiphyseal cartilage, periosteum and marrow. Every morbid irritation, whether resulting from bad air, food and habitation, or from acute or chronic ailment, acts on the whole mass of other tissues or organs, but in the bones only on the growing ends or surface. During the active progress of this disease the bones can be bent by the least possible force and their spongy portions can be easily cut with a knife.

The ligaments are often altered in their structure and become relaxed. This is shown in the yielding spine and the relaxed bone and ankle joints. If the bone deformities remain uncorrected, their relaxation exists even until late in life. In one case, which has come under the author's observation, a condition of bow legs still existing in a man 50 years of age is associated with marked relaxation of the crucial and lateral ligaments, apparently due in part to an effort of the patient to overcome the genu varum by a still further stretching of the internal lateral ligament. However profound may have been the pathological changes in the bones, as soon as the tissues become properly nourished and the child commences to recover from the disease, the bone cells rapidly take up calcareous matter from the blood and dense bone is formed producing the condition called eburnation or sclerosis. Rachitic changes in the osseous tissue do not affect all the bones of the skeleton in equal degree, or even the different portions of any individual bone to the same extent. The bones of one limb may be quite hard, while the other is soft, or the softening may be more marked in the shaft than in the epiphysis or *vice versa.* In operating, I have often noticed that the bone of one limb was softer than that of the other.

Macewen claims that different deformities may be explained by this irregularity in the portion of the bone on which the intensity of the rachitic process falls. Rachitis is not usually developed after the age of five years, although Macewen believes that it may be developed even up to the twentieth year of age, especially after the exanthemata or other debilitating disease.

I have not met with cases of this character.

Rindfleisch thus describes the manner in which the deformities occur: "The bones bend, or what is just as common, they break on one side like a roll of paper, while the other side is simply stretched across the seat of fracture and the central marrow is crushed." (Green stick fracture.)

Rickets being assumed as the general and common predisposing cause of these deformities, what is the element, or the direct and determining cause of the deformity?

The theory that the deformities are the result of muscular action cannot be supported by facts As pointed out by Ogston, the normal shape of the bones is produced, not so much by forces within themselves, as by the action on them of normally acting muscles and such like external agents. It should be remarked that the inferior extremities are more curved than the superior, a fact which did not escape the observation of Glisson. This fact can only be explained by their position and that they support the weight of the body. It has been observed that children who are confined to bed during the acute stage of rickets, and in whom the weight of the body is prevented from being thrown on the lower limbs until the bones are firm, are not the subjects of these curves. Again, those persons whose occupation compels them to stand much of the time on their feet are frequent subjects of such deformities, so much so that the German vernacular for knock-knee is *Bäckerbein* (baker's legs).

The causes determining the special deformity in any given case are various. The intensity of the rachitic process in any particular portion of the bone affected, and the age of the person affected. The more intense the action and the younger the person, the greater will be the number of curves.

The tibial curves belong to the first two or three years of life. If the shafts of the bones are more affected than their extremities, one would expect bow-legs and not knock-knees; if, on the other hand the distal extremities of the femur are more affected and the shafts less we would expect genu valgum as a result. The particular manner in which the weight of the body is directed on the bones, whether the child walks, creeps, sits or shuffles along the floor, each has its effect.

Attention has not been drawn to the fact that in crawling along the floor the weight of the body is thrown on the knees and inner sides of the malleoli, thus tending to produce genu valgum. It should also be remembered that the deformities are frequently but exaggerations of normal curves. Prof. Fischer has drawn attention to the fact that all organs during their growth assume a spiral shape, something like a corkscrew, and that the spiral curve always takes a definite direction, right or left, according to their anatomical relation to a central axis. Many deformities he attributes directly to an increase or diminution of normal spiral curves, as for instance, scoliosis and genu valgum and varum.

SURGICAL TREATMENT OF RACHITIC DEFORMITIES.—While it is true that every case of knock-knee or bow-legs does not demand surgical interference, yet spontaneous cures with rectification of the deformities are exceedingly rare.

While the bones are soft, orthopædic apparatus may be of benefit, but after eburnation has taken place or even become well advanced, it is worthless.

The importance of the early recognition and the early treatment of bow leg and knock knee deformities can not be too strongly emphasized. Although there may be a slight improvement in the deformity, corresponding with a general improvement in the health and nutrition of the individual, yet the expectation of a perfect cure by unaided nature will most frequently end in disappointment.

Far better results, in a shorter space of time, with much less suffering, can be obtained by judicious surgical interference. I fully agree with Roberts that "the surgeon who assumes the responsibility of giving advice or administering treatment in these cases should never be content short of a result which will enable the patient to advantageously receive the weight upon his legs when in the erect posture. The prime function of bone is to sustain weight. If the relationships of the long bones of the lower extremities are not such as will permit of their receiving advantageously the entire weight of the body, an undue strain on the soft parts is inevitable, and sooner or later discomfort or suffering will, as a rule, result. The pain and discomfort which result from the continuance in adolescent and adult life of even a slight amount of deformity is often very great. Especially is this the case if, with increased years, there is a proportionately greater increase of weight of body." A reason for this belief is the frequency of adult cases of deformity seen on our streets. I have frequently counted as many as 10 to 15 in a few hours' walk.

In Glasgow, notwithstanding the enormous work of Macewen and other surgeons, an equal number or cases may be counted in a walk of a few minutes, showing conclusively that many cases never become corrected spontaneously.

"Osteotomy," says Macewen, "in its broadest acceptation may be defined as a section of a bone.

"It has, however, been regarded in a much more restricted sense, the term being applied to such divisions of bones as have been proposed and undertaken for the relief of deformity, for the rectification of badly united fractures and for the straightening of limbs affected with osseous anchylosis, which are fixed in a bad position." (*Osteotomy*).

The first osteotomy for the rectification of anchylosis was performed by Dr. John Rhea Barton in 1826. Langenbeck, in 1852, made a division of the femur for anchylosis of the hip joint by perforating the bone with a drill through a small wound in the soft parts, and then divided the bone with a narrow saw. To this operation he gave the name of subcutaneous osteotomy.

In 1875, Volkmann, of Halle, operated antiseptically on two cases of anchylosis of the knee-joint, and in the same year Macewen performed a similar operation. These two influences, the introduction of Listerism and the subcutaneous method of Langenbeck have made osteotomy one of the safest operations in surgery. Without the advent of antisepticism osteotomy would have remained an operation confined to the few, or would have entirely receded from the field of surgery. The honor of introducing antiseptics into osteotomy is due to the distinguished Volkmann, of Halle.

Various instruments have been employed for the performance of osteotomy, including trephines, bone perforators, gimlets, chain saws, round saws, ordinary saws, trocar saws, and electric saws, some for subcutaneous and others for open wounds; the last and best of all is the chisel. There are two forms, in one the edge is beveled, as in the ordinary carpenter's chisel; in the other the blade has the shape of an elongated inclined plane, and to this Macewen has given the name "Osteotome" in order to distinguish it from the chisel proper. (Fig. 3).

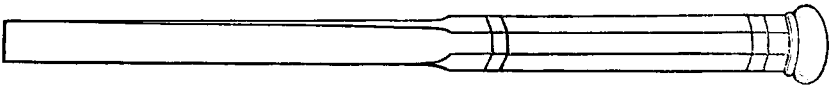

FIG. 3.—MACEWEN'S OSTEOTOME.

The osteoclast is an instrument of tremendous and brutal power which I hope will never be generally adopted by American surgeons. As some one well puts it, "the osteoclast should become an historical surgical reminiscence; while Macewen's chisel should be canonized as the ideal scientific corrector of bone deformities."

Osteotomy may be either linear or cuneiform. A section of bone by *linear osteotomy* is made through a small wound just large enough to admit the osteotome. The bistoury should be maintained in situ to serve as a guide to the osteotome which is inserted at its side.

The osteotome is introduced in a line with the incision in the soft parts; when it reaches the bone it is turned to the direction that the osseous incision is to be made. In selecting a site for the incision in the soft parts, it should be made so as to avoid wounding any of the larger blood-vessels. In the hand of the expert operator the osteotome becomes a probe and the sensations conveyed through the instrument enable him to ascertain all that could be known by the introduction of the finger. The osteotome should be directed so as to cut away from any important structures that lie close to the bone. At the same time, the sides of the instrument being blunt, it may be used so as to turn aside the soft tissues, meanwhile keeping the cutting edge in contact with the bone. The osteotome is driven through the bone by pretty firm blows with the mallet. For this purpose I am in the habit of using a good sized carpenter's mallet. After each blow the instrument is moved from side to side at right angles to the bone, in order to prevent its becoming too firmly wedged in the bone. In dividing large bones it is well to use in succession osteotomes of two or three sizes Section of the bone should be commenced with the largest osteotome. After a time the instrument becomes wedged and is difficult to move. It should then be withdrawn and the next smaller size substituted. A section thus made is more V-shaped. In performing cuneiform osteotomy a large open wound must be made and the operation is not subcutaneous. In performing either subcutaneous or cuneiform osteotomy strict antiseptic precaution should be observed; by this means we secure perfect immunity from inflammatory complication and a compound fracture heals as a simple fracture.

The patient should be profoundly narcotized before commencing the operation, as any movement of the limb produced by muscular contraction might disturb the relation of the knife or chisel to the bone and wound some structure not intended to be disturbed. The limb should then be rendered bloodless by means of an Esmarch's bandage. The limb should be thoroughly cleansed by means of soap, water and brush, shaved and then washed with ether in order to remove all fatty and sebaceous substance. It is then wrapped in a towel wet in a 1-1000 corrosive sublimate solution until ready for the incision. Having selected the site of the incision the bone should be reached as quickly as possibly, by a sharp, clean incision, produced by a single stroke of the knife. Other things being equal, the line of incision should be parallel to the fibres of the muscles penetrated. Commencing with the largest and using the other sizes in succession, the incision thus made corresponds more nearly to a wedge. Under no circumstances should the osteotome be used as a lever to pry the bone apart as it will result in the breaking of the instrument.

The instrument should be grasped firmly in the left hand, the border of which rests on the limb, just above the wound. In this way the osteotome is under perfect control and any deviation which might inadvertently be given to it by the mallet can be instantly checked. (See Fig. 4). The chisel should be made to traverse the deeper layers of bone in a fan-like manner. When the section of the bone is nearly completed the osteotome is withdrawn and the deformity rectified by fracturing with the hands the remaining bridge of bone. During the section the wound should be kept wet with $^1/_{2000}$ sublimate solution, or if there is any reason to fear that the antiseptics have not been perfect, on the removal of the osteotome, the small nozzle of an irrigator may be introduced and the wound irri-

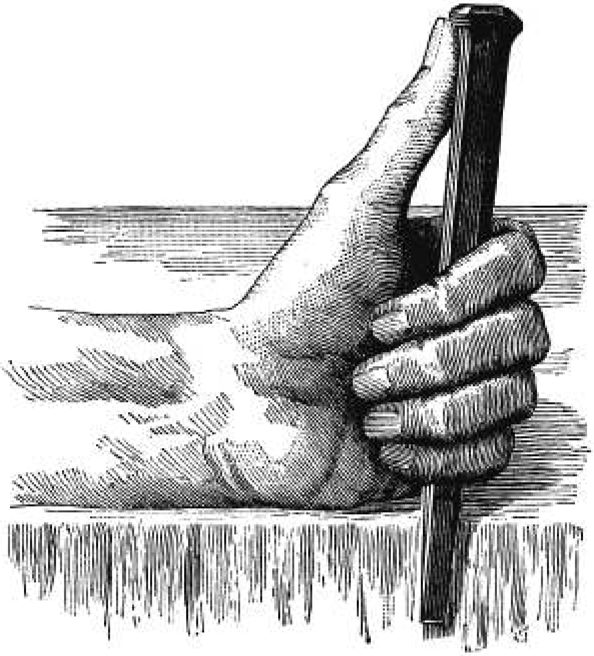

FIG. 4.—MANNER OF HOLDING THE OSTEOTOME.

gated with the sublimate solution. After the deformity has been corrected a wet sponge is secured over the wounds with a few turns of a roller bandage and the Esmarch bandage removed.

The sponge should remain in place while the other limb is being operated upon, or until the limb is ready to be dressed.

The hæmorrhage after a subcutaneous osteotomy is slight, I have never seen enough to cause any anxiety.

*Cuneiform Osteotomy.* In anterior curvature of the tibiæ and angular curvatures of the long bones a wedge of bone has to be removed in order to correct the deformity. For this purpose a chisel with a straight cutting edge on one side is used and the section is made through an open wound.

An Esmarch's bandage having been applied an incision is made over the crest of the tibia, parallel to the long axis of the limb directly down to the bone at the site of the greater curvature. The wound should be large enough to admit the finger and to enable the operator to see what he is doing. I have sometimes made the incision at right angles to the axis of the limb. While this facilitates the operation the hæmorrhage is apt to be greater. The periosteum should be divided in the same line with the incision through the soft parts.

It is sometimes recommended to make another incision at right angles to the first at its middle portions. This complicates the wound and is of no material advantage. The periosteum should be well separated from the bone at the point where the wedge is to be removed. The size of the wedge that it is necessary to remove should be accurately determined before the operation, and marked off with a pair of calipers. When a large wedge is to be removed it is better to cut it out in several small pieces, first a small superficial wedge, then a shaving on each side until the desired amount of bone is cut out. The shape of the normal bone does not afford a guide in the removal of the wedge, as the shape of the distorted bone is greatly altered in its contour.

The deformed tibia will often be found greatly flattened from side to side. If the chisel be kept within the periosteum important soft structures cannot be injured. If the size of the wedge has been accurately calculated, when the deformity is corrected the cut surface of bone will just come in apposition and may be held in position with a suture of strong catgut.

*Dressing of the Wound.* After the circulation has been established, any bleeding vessels that are liable to cause trouble are to be secured with catgut ligatures. The edges of the periosteum are to be united with catgut sutures, a few strands of catgut placed at the angles of the wound for drainage, and the skin united. It has been sometimes recommended that a counter opening be made at the apex of the wedge and several horsehair-drains inserted.

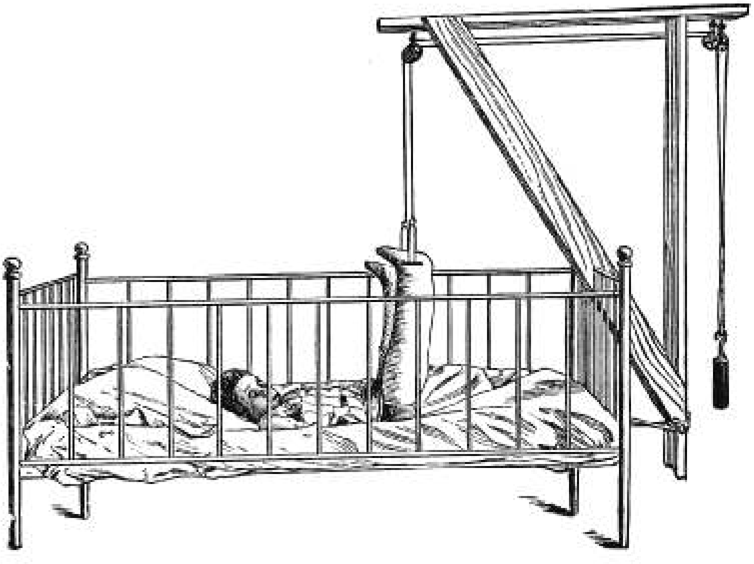

FIG. 5.—THE AUTHOR'S METHOD OF SUSPENDING THE LIMB AFTER OSTEOTOMY.

Macewen treats the wound openly. The wound should be dusted with iodoform and covered with a strip of Lister's protective. The limb is then enveloped in a mass of sublimate gauze and absorbent cotton and neatly bandaged. After both limbs are dressed a plaster bandage is applied and the limb is suspended, as in Fig. 5, a method which I have found of exceedingly great advantage in my practice.

Macewen uses a splint consisting of a back, an outside and foot piece (Fig. 6), the padding being arranged so as to slightly over-correct the deformity. The essentials for success are the maintenance of the limb in a fixed straight position and the keeping the body at rest. I think these requirements may be more easily accomplished by the position which I suggest. The wound heals by first intention. The wound may be left for three weeks when the dressing should be removed and any slight remaining deformity corrected and the wound dressed for another three weeks. I believe, however, that the best results can be secured by placing the limb in a temporary splint for 24 hours when the dressing is removed and the limb put up in a permanent dressing and splint.

It is often found that the first dressing becomes saturated and hardened by the dried blood and loses its antiseptic properties.

FIG. 6.—MACEWEN'S SPLINT.

*Cases Suitable for Operation.* Genu valgum or knock-knee may be defined as a deformity at the knee-joint in which a line drawn from the head of the femur to the middle of the ankle-joint passes outside the center of the knee-joints and in which the internal malleoli cannot be made to touch when the limbs are in an extended position.

Several different operations have been performed for the relief of genu valgum. The one which I think gives the best results is that of Macewen.

In performing this operation the incision in the soft parts is made on the inner side of the limb, at a point where the two following lines bisect one another; a line drawn a finger's breadth above the level of the upper border of the external condyle and in a line parallel to, and half an inch in front of the tendon of the adductor magnus. By making the incision directly down to the bone it is impossible to wound any important structures.

In July last I had the opportunity of seeing that master of osteotomy, Dr. Macewen, perform his celebrated operation for genu valgum. A small quick incision, with a few rapid strokes of the mallet, the chisel divided the superficial shell of the inner surface of the femur, then the chisel was rapidly driven in a fan-shaped direction into the cancellous tissue of the bone and the division completed. The other limb was likewise operated upon with the same degree of rapidity and precision. The deformities were at once corrected, the limbs dressed and immobilized in a splint.

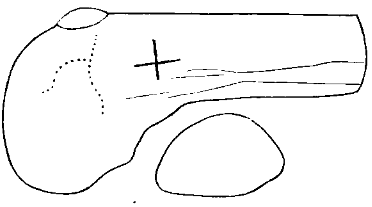

FIG. 7.—DIAGRAM SHOWING POINT WHERE THE FEMUR IS DIVIDED IN MACEWEN'S OPERATION.

Curvatures of the tibia may be lateral, anterior or antero-lateral; the bending may be confined to the lower third of the bone, just above the malleoli, it may involve the whole bone, or there may be a short curvature at its lower third and then a long one above, or the bone may have one long anterior curve. An anterior curve above the ankle and a compensatory posterior curve just below the knee is a frequent deformity. This deformity frequently gives rise to a condition of hyperextension at the knee-joint.

In these cases when the deformity is slight it may be corrected by a simple osteotomy, but when the deformity is pronounced, a series of osteotomies, or the removal of several wedges is necessary to rectify them. In one case I performed as many as eighteen sections of bone on one patient.

In well marked cases of anterior curvature after removal of the wedge of bone it will be found that the deformity cannot be overcome until the tendo Achilles is divided subcutaneously.

I have had to perform tenotomy of the tendo Achilles in four cases. Out of a series of one hundred and fifty-eight sections of bone, in only two cases, in which cuneiform osteotomy was performed, the skin wound failed to unite owing to pressure of the splint, but in none of the cases has there been suppuration or non-union.

I append herewith abstracts of seventeen cases in illustration of the views presented.

CASE I.—Lena H., æt. 12 years. History of rachitis. Marked genu valgum. When standing with the internal condyles of the femur touching, the feet were separated a distance of twenty inches.

Jan. 8, 1885, supracondyloid osteotomy of both femora. Recovery attended by no bad symptom; in three week's the dressings were removed and the wounds found to be healed and the limbs in good position. At the end of the 7th week the patient was walking about.

CASE II.—Ruby H., æt. 8 years, sister of Case 1. Has marked genu valgum of rachitic origin, in both limbs. When standing the feet were separated a distance of 22 inches.

Jan. 8th., supracondyloid osteotomy of both femora. Antiseptic dressing, plaster splints and suspension. Made an easy recovery. Redressed at the end of 3 weeks; wounds healed; limbs in good position.

CASE III.—James H., æt. 10 years. All the bones presented slight rachitic changes. In the forearm there was a marked posterior curvature of the ulna and radius.

On Feb. 5th I performed subcutaneous osteotomy on both the ulna and radius, the limb was rectified and dressed with a plaster splint which was changed at the end of three weeks, when the wounds were healed; plaster re-applied for another two weeks.

These three cases belonged to the same family. The mother has had seven children, all of whom are rachitic.

CASE IV.—Eighteen sections of bone. Jane S., æt. 9 years, entered the hospital in April, 1886. She was in a poorly nourished condition, and presented marked rachitic deformities of all the long bones.

The femora present anterior and lateral curvatures with great depression of the internal condyles.

Below the knee, in both legs, there is a marked posterior curvature with outward rotation of both tibiæ and fibulæ. About the middle portion of each leg there is a marked anterior and inward angular deformity of both bones of the leg. Just above the ankle there is marked anterior curvature of both limbs.

On April 24th I performed cuneiform osteotomy on tibiæ and fibulæ of both legs for the correction of the most marked deformities. The limbs were immediately put up in plaster splints; these were not removed for a period of three weeks.

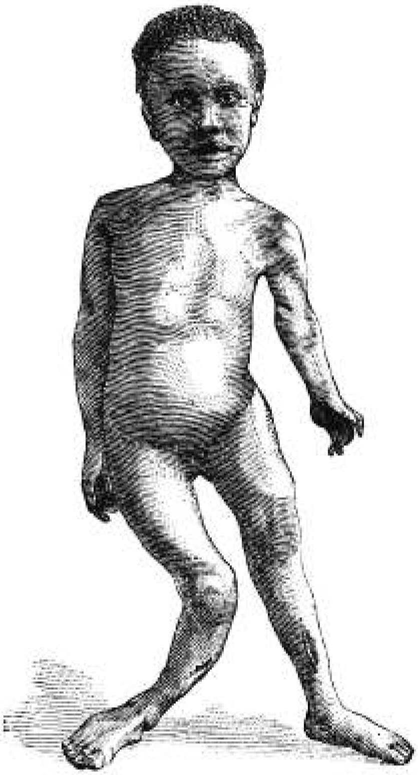

FIG. 8.—MULTIPLE RACHITIC DEFORMITY AFTER PARTIAL CORRECTION. From a photograph of Case iv.

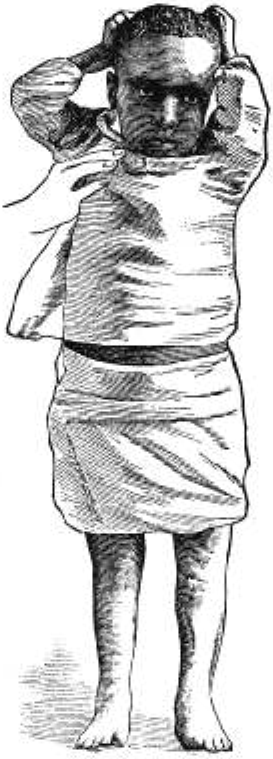

FIG. 9.—MULTIPLE RACHITIC DEFORMITY AFTER COMPLETE CORRECTION. From a photagraph of Case iv.

When the wounds were found to be healed and the worst deformity corrected, the plaster splints were re-applied for another three weeks, when they were removed and the patient was allowed to walk around. Fig. 9 shows the patient after these four osteotomies. Previous to the operation, on walking, the inner portion of the leg touched the ground.

Oct. 6 I performed Macewen's supracondyloid operation on both femora. Nov. 20th, cuneiform osteotomy on both tibiæ and fibulæ. Dec. 28th, cuneiform osteotomy of right lower tibia and fibula.

From all of these operations the patient has recovered without the least trouble, and there has not been a particle of suppuration in either wound. May 8, 1887, cuneiform osteotomy of tibiæ and fibulæ above ankle. June 2, cuneiform osteotomy of upper left tibia and fibula. Oct. 12, cuneiform osteotomy, right tibia and fibula. Fig 9 shows the patient in her present state; she is able to walk with ease and comfort and feels proud and happy.

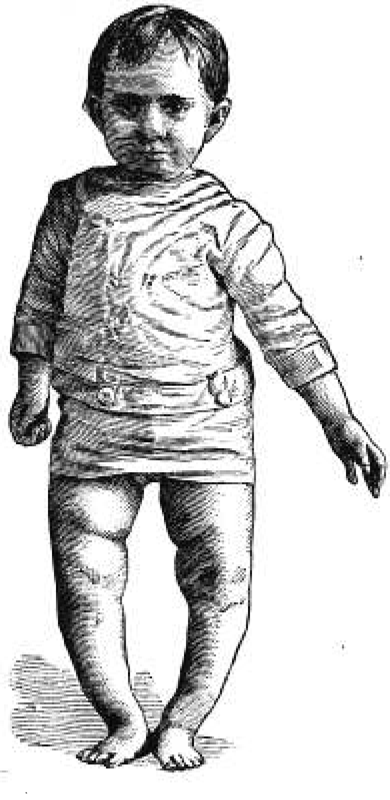

FIG. 10.—CASE OF BOW LEGS. From a photograph of Case viii.

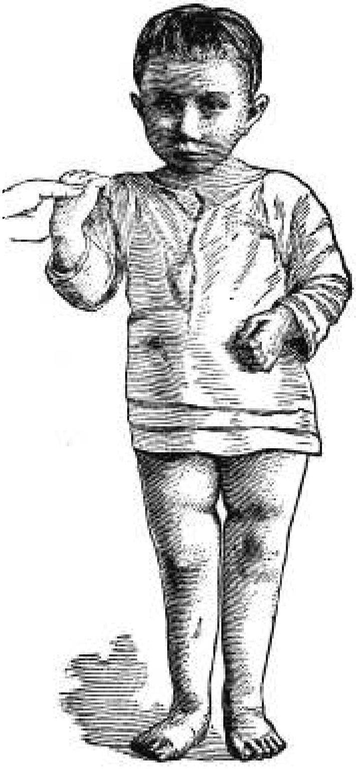

FIG. 11.—CASE OF BOW LEGS CORRECTED. From a photograph of Case viii.

CASE V.—Samuel C., æt. 9 years, presents a well marked example of rachitic deformity. The teeth are deficient. The femora have an anterior curvature and both internal condyles are much depressed.

The tibiæ present several marked lateral and antero-posterior curvatures.

He walks with difficulty. There is also well marked lordosis. On July 12th I performed Macewen's operation on both femora. Dressed as usual.

Wounds found healed when the dressings were removed at the end of three weeks. Oct. 3d I performed cuneiform osteotomy on both tibiæ and fibulæ just above the ankle, for marked lateral curature

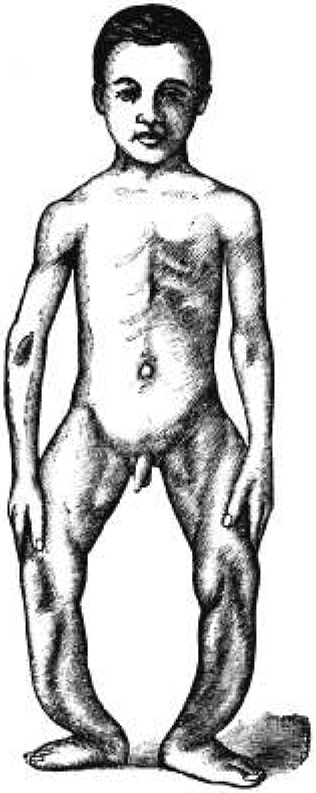

FIG. 12.—ANTERIOR VIEW OF MULTIPLE DEFORMITY. From a photograph of Case xii.

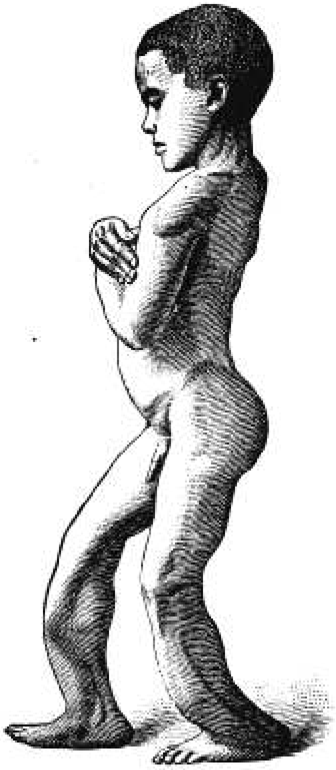

FIG. 13.—LATERAL VIEW OF MULTIPLE DEFORMITY. From a photograph of Case xii.

Nov. 3 dressings removed, wounds healed. A month later the tibiæ and fibulæ above were operated upon for antero-posterior curvature.

CASE VI.—Lena F., æt. 3 years, was admitted Sept. 5th. She presented a well marked example of bow legs. Subcutaneous section of tibiæ and fibulæ of both legs at the upper portion was performed Oct. 5. Recovery normal.

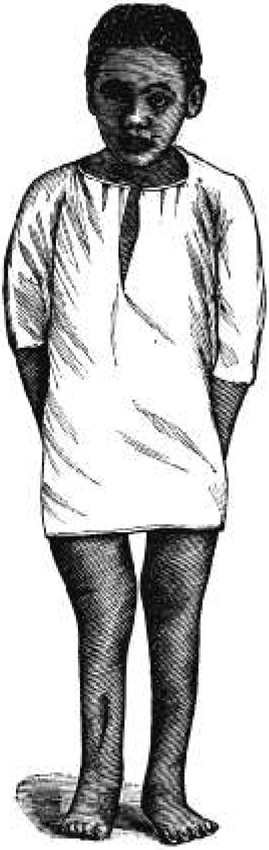

FIG. 14.—CASE OF MULTIPLE DEFORMITY CORRECTED. From a photograph of Case xiii.

CASE VII.—Frank P., æt. 8 years, presented a well marked example of genu valgum. On Oct. 7 I performed Macewen's operation on both femora; recovered without incident, splint removed at the end of five weeks.

CASE VIII.—Lillie D., æt. 3 years. Well marked example of bow legs, had been treated mechanically at one of the Brooklyn orthopædic dispensaries for over a year but without material benefit.

Nov. 18th, 1886, I performed osteotomy on both legs, dividing the tibiæ and fibulæ. She made an uninterrupted recovery. Patient before and after operation is shown in Figs. 10 and 11.

CASE IX.—James Lowery, æt. 4 years, was admitted into the hospital with a marked curvature of both bones of the legs, especially prominent just above the ankles and below the tibial tuberosities. On Nov. 27, I made a section of the fibulæ and tibiæ of both legs.

The deformities at these points were corrected but a slight angular deformity remained just above the ankle of the left leg. The parents were, however, so well satisfied with the result of this operation that they did not consider another operation necessary.

CASE X.—Edna F., æt. 3 years. Entered the hospital March 2nd. An example of genu valgum. Macewen's operation April 14th. Splints were removed at the end of five weeks, when the limbs were found to be in good condition.

CASE XI.—Anna B., æt. 3 years. Entered the hospital May 16th. Outward curvature of the legs. Cuneiform osteotomy May 19th. Recovery uninterrupted.

CASE XII.—Frederick M., æt. 10 years. History of rachitis. All the bones presented marked evidence of rachitis. Teeth deficient and all the long bones deformed. The femora presented anterior and lateral curvatures with depression of internal condyles.

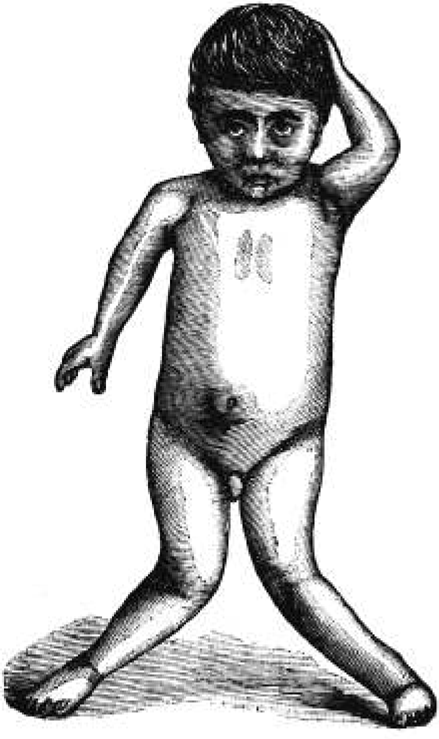

FIG. 15.—CASE OF MARKED GENU VALGUM. From a photograph of Case xiv.

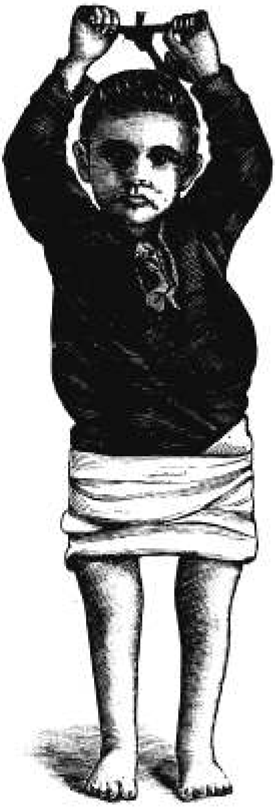

FIG. 16.—CASE OF MARKED GENU VALGUM CORRECTED. From a photograph of Case xiv.

The tibiæ were flattened with anterior and lateral curvatures. Cuneiform osteotomy of both tibiæ and fibulæ May 18th, 1887, with correction of angular curvatures above ankle. In order to straighten the limbs I had to tenotomize both tendones Achillis.

Wounds healed without suppuration.

Oct. 13th, Macewen's operation for the correction of genu valgum. Nov. 15th, cuneiform osteotomy for correction of anterior curvatures of tibiæ.

Patient discharged Dec. 30, with limbs in good position. Figs. 12, 13 and 14 illustrate his condition at different stages.

Case XIII.—Brunetto C., æt. 4 years. Entered June 10th. Compound rachitic deformity. Cuneiform osteotomy of tibiæ and fibulæ of both legs June 30th.

Oct. 25th, Macewen's operation. Recovery.

Case XIV.—John Binca, æt. 4 years, was admitted August 14. His condition at that time is shown in Fig. 15. On Oct. 18 I performed Macewen's operation on the femur. The result is shown in Fig. 16. Jan. 4, 1888, I performed double cuneiform osteotomy on tibia and fibula of left leg. On Jan. 25 I performed similar operation on the right leg. April 6, cuneiform osteotomy of both tibiæ and fibulæ for posterior curvature.

Case XV.—Harry B., æt. 7 years, entered Oct. 19. He presented marked genu valgum and tibial curvature. Nov. 11, supracondyloid osteotomy. Jan. 25, 1888, I made cuneiform section of upper tibiæ and fibulæ of both legs, after the manner of Volkmann, for correction of some remaining genu valgum and posterior curvature of tibiæ.

April 12, cuneiform osteotomy of bones of both legs.

Case XVI.—Bessie L., æt. 5 years. When 2 years old was treated for muscular debility and infantile paralysis. Supracondyloid osteotomy Oct. 20.

Case XVII.—Lucy N , æt. 6 years. Rachitic history, marked rachitic deformity of legs.

Nov. 5, supracondyloid osteotomy. Jan. 24, cuneiform osteotomy of both tibiæ and fibulæ for anterior curvature above ankle.

April 30, cuneiform osteotomy of both tibiæ and fibulæ at the upper part for posterior curvature.

Case XVIII.—James M., æt. 4 years. Rachitic history. Complicated deformity of legs.

Nov. 11, I performed supracondyloid osteotomy on both femora. Jan. 24, cuneiform osteotomy of both tibiæ and fibulæ for anterior curvature.

April 30, cuneiform osteotomy of both tibiæ and fibulæ at upper third.

Case XIX.—Carrie —., æt. 7 years. Rachitic history. Deformity well marked in tibiæ and fibulæ. Illustrated in Figs. 17 and 18.

Feb. 3, I removed a large wedge from both tibiæ and fibulæ for correction of anterior and lateral curvature. In order to fully correct the deformity I had to tenotomize both tendones Achillis.

April 14, cuneiform osteotomy of tibiæ and fibulæ at upper third for anterior curvature.

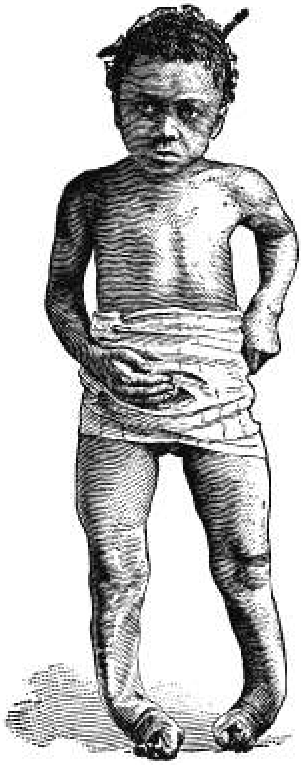

FIG. 17.—RACHITIC DEFORMITY OF UNUSUAL TYPE. From a photograph of Case xix.

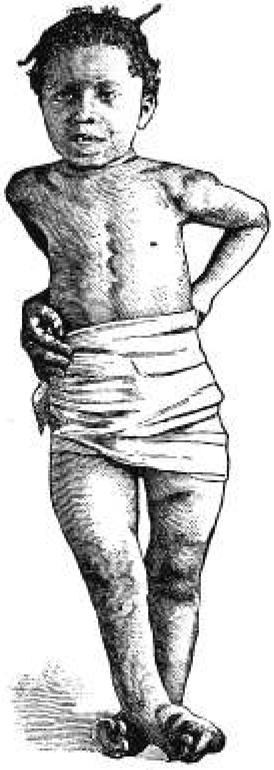

FIG. 18.—TYPICAL CONDITION OF TEETH IN RACHITIS. From a photograph of Case xix.

CASE XX.—Lizzie B., æt. 7 years. Rachitic history; different portions of the body presented marked deformities of a rachitic nature. The head was markedly elongated antero-posteriorly and flattened from side to side. Fig. 19. The upper and lower extremities presented various deformities of a complex nature.

Feb. 26, double cuneiform osteotomy of both legs above the ankle for anterior and lateral curvature.

April 25, double supracondyloid osteotomy.

June 29, section of both ulnæ and radii for posterior curvature.

Case XXI.—Charles F., æt. 7 years, presented a very aggravated type of rachitic deformity.

Feb. 25, double cuniform osteotomy at the lower third of the legs for marked angular deformity.

The operation of double osteotomy by the supracondyloid method was done April 28.

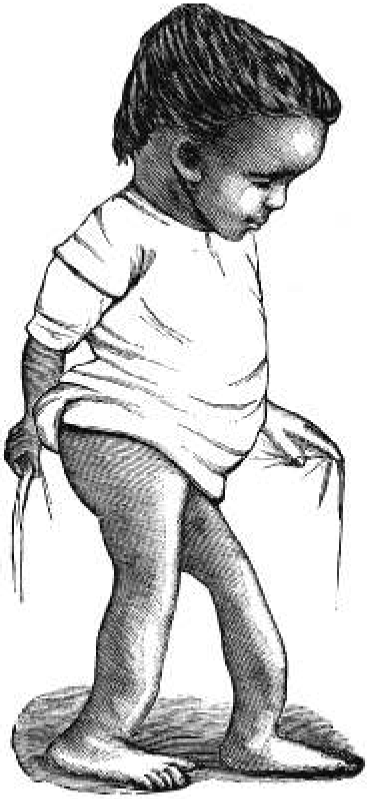

Fig. 19.—Multiple Rachitic Deformity, Showing Elongated Head. From a photograph of Case xx.

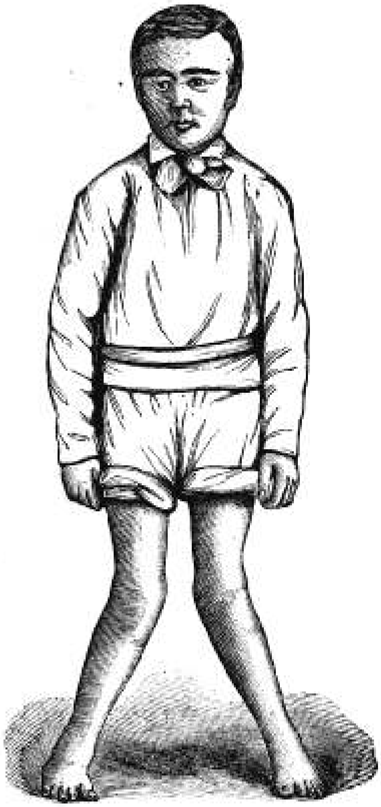

Fig. 20.—Genu Valgum Existing in a Boy Æt. 15 Years From a photograph of Case xxvi.

June 29th, section of both ulnæ and radiæ for marked curve in the forearm. Recovery from these several operations was perfect.

CASE XXII.—Elizabeth J., æt. 12 years. Genu valgum with anterior curvature of tibiæ.

April 24, supracondyloid osteotomy.

June 19, section of both tibiæ and fibulæ.

Deformity corrected.

CASE XXIII.—Posquet Sarronto, born of Italian parents, æt. 5 years. Rachitic history. Genu valgum. Mallorli separated ten inches ; posterior curvature of tibiæ, Rachitic spine.

Jan. 4, supracondyloid osteotomy.

April 20, cuneiform osteotomy of both tibiæ and fibulæ. Plaster dressing. Recovery normal.

CASE XXIV.—Wm. D. æt. 5 years, typical form of genu varum, Sept. 6, section of tibia and fibula of each leg at two points. Deformity. corrected; antiseptic dressing and plaster splint.

Dressings and splints removed at the end of eight weeks.

CASE XXV.—Tommy Fisman, æt. 5 years, exaggerated form of bow legs of marked degree. Sept. 10, section of both tibiæ and fibulæ at the upper and lower angles of the curvature. Antiseptic dressing and plaster suspension. Dressing removed at the end of eight weeks, wound healed and deformity corrected.

CASE XXVI.—Wm. J. æt. 12 years, a typical example of genu valgun, malleoli separated twenty inches. Fig. 20. Jan. 20, supracondyloid osteotomy. Plaster dressing and suspension. Temperature normal.

CASE XXVII.—R. M. æt. 4 years, genu valgun. Dec. 2,supra-condyloid osteotomy. Plaster dressing and suspension. Dressing removed at the end of the seventh week.